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RECENT APPLICATIONS OF FABRIC STRUCTURES IN VENEZUELA

JAIME A. LEÓN*, CARLOS H. HERNÁNDEZ†

* Architect. Project Manager Grupo Estran C.A.
Caracas, Venezuela
e-mail: jaime@grupoestran.com, web page: http://www. grupoestran.com

† Associate Professor Instituto de Desarrollo Experimental de la Construcción (Institute of Experimental Construction Development). School of Architecture. Universidad Central de Venezuela.
Caracas, Venezuela
e-mail: chhm@alum.mit.edu

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Summary. The paper presents some examples of fabric structures designed and built by the company Grupo Estran in Venezuela, describing the different phases within the design method: from the first draft and the use of specialized software to develop double curvature surfaces as architectonic forms, to its manufacture and erection. Furthermore, the paper discuses the interaction of this type of structures with its context and its contribution to create and enhance the architectural space.

1. FIXED TEXTILE COVER BLEACHERS OF THE BARQUISIMETO BASEBALL STADIUM. BARQUISIMETO, LARA STATE. VENEZUELA.

1.1 Proposal

In 2009 the state government of Lara began the intervention of the "Antonio Herrera Gutiérrez" baseball stadium (fig. 1)—home of the professional baseball team *Los Cardenales de Lara*—so that it can meet the parameters established in the new agreement between the Major League Baseball and the Venezuelan League of Professional Baseball.

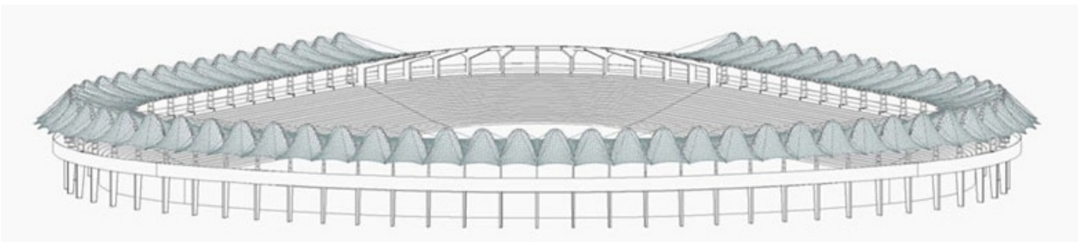


Fig. 1. General view.

The new covered area has an approximate total of 3,360.00 sqm on a single level. There are two wings, each with a rectangular projection of approximately 20 m wide and 85 m long.

Each wing is made up of twelve modules (fig. 2 and 3). The structural modulation matches the existing one in the reinforced concrete structure of the bleachers. Support is located in the upper part of the bleachers from where the metallic arms that cover the bleachers fly towards the front, and the traffic hall towards the back part.

Its shape, has a straight line in the edges and transitions into a sequence of twelve parabolic convex arches in the center. Its maximum height is approximately 9.90 m from the floor of the top hall of the bleachers and the minimum is approx. 3.65 m from the same reference point. The average from the ground is about 17.40 m.

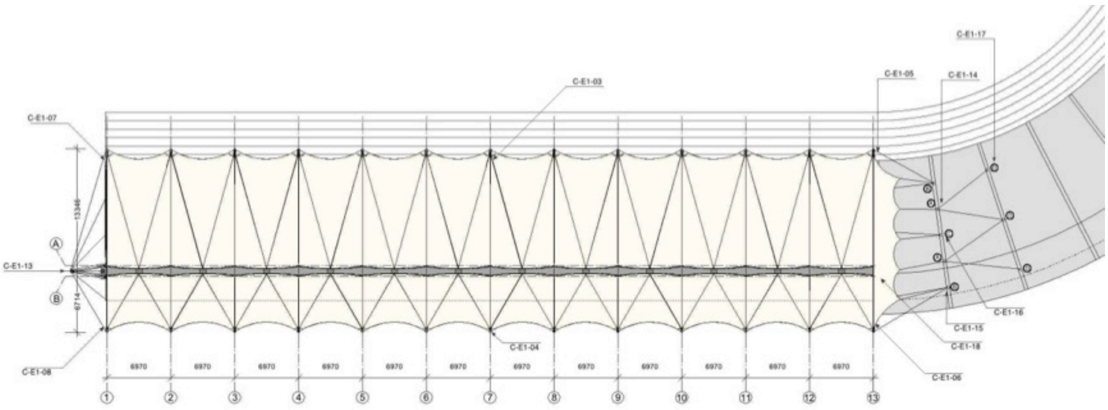


Fig. 2. Left wing, top view.

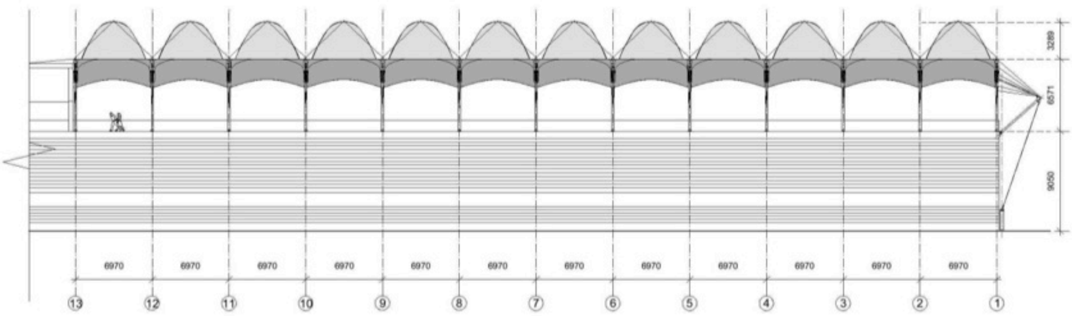


Fig. 3. Left wing, field view.

The structural module (fig. 4) is made up of a pair of compound pillars built with two structural tubes, Ø194 mm separated by 1300 mm and joined by Ø 140 mm separators, forming a staircase, which becomes narrower towards the upper part, where some terminals receive a parabolic 6970 mm span arch, which connects the pillars using four bolts. Bolts were used to connect the structural steel components aiming to reduce assembly time. The arch is built with two tubular Ø140mm components calandared at three points, which are joined by Ø 89mm tubes.

From this central structure, two 12 m long trussed struts fly towards the side of the bleachers. The trussed struts are formed by three tubular Ø 114 mm joined by flat bar triangles which become sharper towards the ends, where we find the heads that allow them to be connected, on one side with the head of the pillar, and on the other, with the edge reinforcement of the membrane. On the opposite side, over the traffic hall, two 6 m long struts, this time built with a single Ø140 mm tube.

From the faces of the arch, membranes that take the parabolic shape of the arches go out and down until they turn into a straight line at the ends of the struts. The membrane is fixed in a continuous manner along the struts with stainless steel flat bars. The outer edge finishes off in a Ø 12 mm reinforced edge, which connects at the ends of the struts.

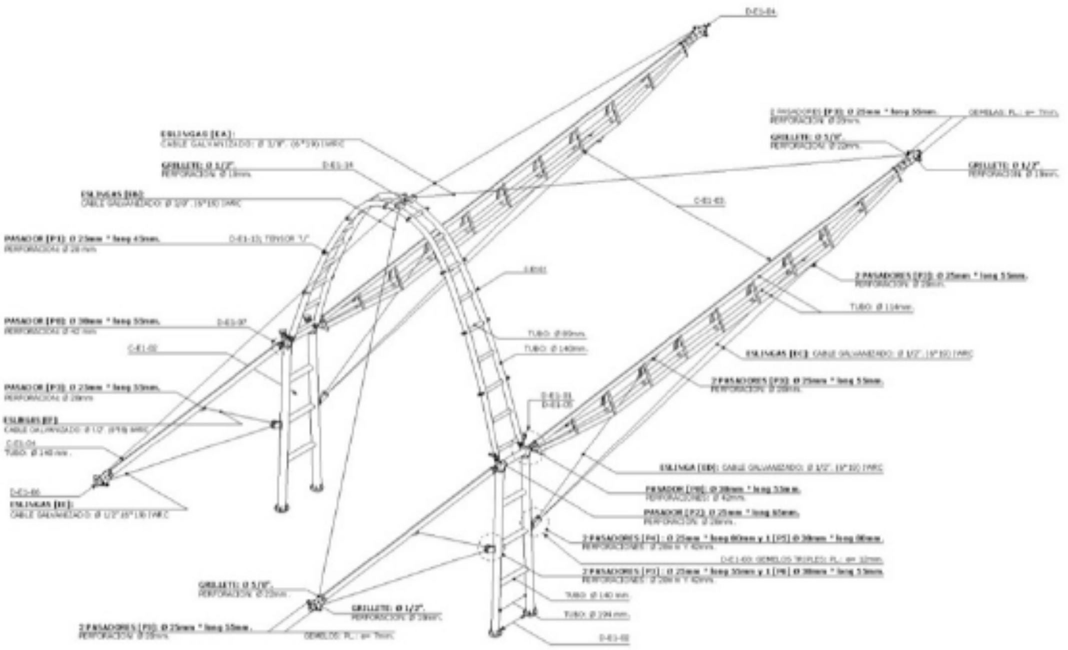


Fig. 4. Structural module.

Towards the arch, the connection is made in eight points, via U type tensors, and it is with these that the membrane will be tensed.

The Membranes support the struts, but, due to the difference in length of the projectings, we manipulated the curvatures in the aim to balance the efforts transmitted to the arch. This way, the big membrane has a bigger curvature than the small one (fig. 5). To prevent the struts from rising due to the effect of the suction load, steel cables go from the struts to the pillars. These steel cables finish balancing the structural system in the vertical plane.

In the horizontal plane, the forces are not compensated internally in the module. One module balances the following, until reaching the ends, where the circuit ends. At one end, the forces are taken to the concrete structure using a tripod, which receives the cables from the front and hind reinforced edges, and at the other end, it is closed against the concrete structure of the roof of the central bleachers.

The profile of the module has an inclination that mimics the one on the existing concrete roof over the main stand, which allows us to include a draining system for rain water. Between modules, and over the arms, the rain water is collected through a fabric canal, and finally taken to the back end through a stainless steel funnel.

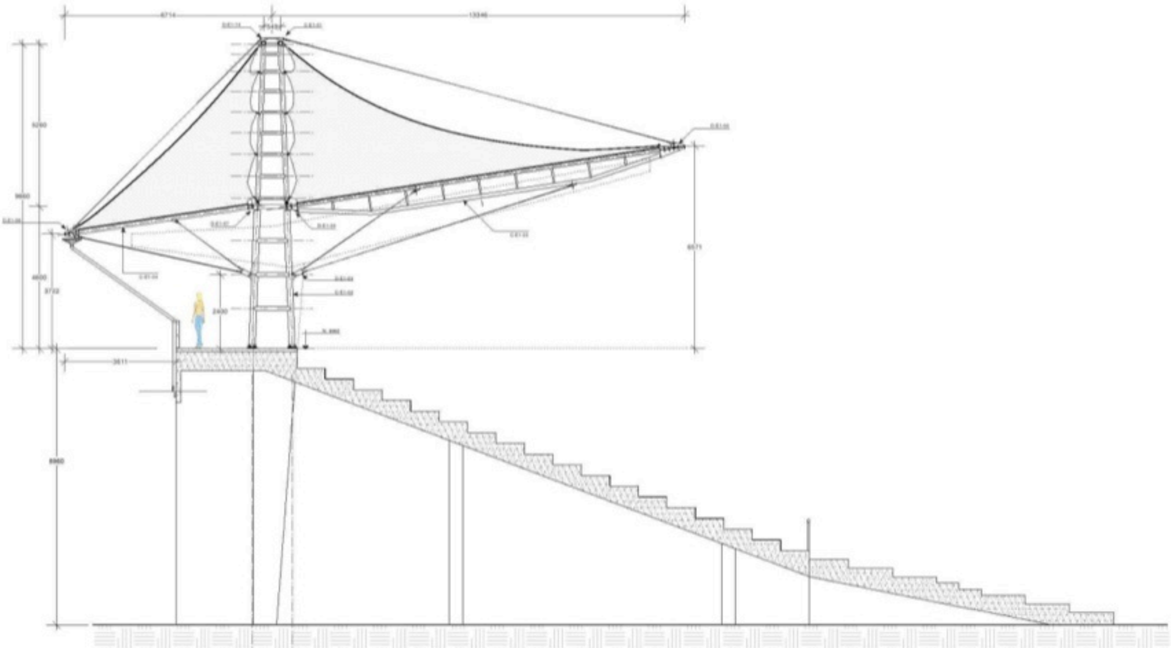


Fig. 5. Bleachers and membrane roof section.

1.2. The membrane

NAIZIL Big Cover type II membrane (blackout) was used. Aside from fulfilling the necessary structural and resistance requirements, it has the Rotofluo W treatment, which provides it with a lifespan expectation of more than 25 years.

Fig. 6 and 7. Real-size prototypes.

Once we obtain the final patterns to cut the membrane and before starting mass production of the membranes, they were verified by building two physical scale models and two real-size prototypes (fig. 6 and 7). The length of the steel cables for the reinforced edges and the performance of the corner plates were also verified.

Each module was sent to the assembly site with most of the steel cables and corner plates in place, to avoid inasmuch as possible manipulation at the site.

It is noteworthy that the same textile material was used to solve the rain water collecting canal. To one of the side ends of each membrane module was welded the strip that served as a canal and to the other a pocket that allowed for stapling, posterior and in site, of the canal strip of the neighboring module. All the modules also had—integrated in the main membrane—the overlap for the final finishing against the arch and the polycarbonate sheets.

1.3. Assembly

Fig. 8. Assembly and structure erection.

The entire structure was designed for its components to be assembled at the site, using bolts. With the help of cranes, the new metallic pillars were placed in their position and fixed to the previously built pedestals. The 12 m struts were passed to the side of the bleachers where they are laid for support on two workbenches. The access of the cranes is through the periphery of the stadium, behind the bleachers. From these positions it was difficult to pass the struts if the arches were placed first. On the other hand, this allowed other membrane connection operations to be carried out, while the arches were being raised and connected to the pillars (fig. 8).

The membranes were connected to the struts using a system consisting of stainless steel flat bars fixed to a bar, which was welded to the struts' upper tubular. This allowed the membrane to adopt different inclinations with respect to its anchorage.

Fig. 9. Assembly and structure erection process.

Once the membrane was placed, the hind ends of the arms are raised to be connected to the node of the pillar, from which they will pivot when taken to their final position. The workbenches facilitate this movement and prevent the struts from banging against the bleachers. The small membranes are assembled together with the short struts in three module groups, at the parking level, to be later raised, using cranes, to the top part of the hall where they are connected to the pillar node.

At first we thought of raising the arms gradually and spaced out, but due to delays in the construction, the assembly time was reduced to a few days. We chose instead to use two cranes located in the back to raise an entire wing at once (fig. 9).

Each crane allowed to lift simultaneously groups of three struts, leaving the side and internal struts—not connected to the cranes—to be lifted by the other struts, using the reinforced edges, and finishing off manually, using lever chain pullers anchored to the cover structure or the existing concrete structure at the site. The free ends of the arm's steel cables were tied with ropes, which allowed the assembly team—that was waiting at the ridges for the arms to reach their position—to connect them (fig. 10). These and other provisional ties were used during the entire procedure to ensure the stability of the structure and its components while they were being manipulated and taken to their positions.

Fig. 10 and 11. Assembly and structure erection.

The assembly of the components and membranes of the two wings of bleachers was carried out simultaneously and with similar procedures. To lift the covers of the right wing, the strategy used the support of a third crane, which accounted for some time saving.

When the struts were raised to their positions, the membranes hung, showing the designed shape but upside down. While they were being raised, they were tied to prevent damage due to the wind. Using a system of pulleys, they were raised to the center of the arch, from where the rest of the established points were connected.

The mechanism used to introduce tension to the membranes is exclusively through these points, since the connections located at the ends of the arms are fixed and do not allow additional graduation (fig. 11). This procedure was repeated in each membrane. The lower steel cables of the arms were connected and the final tensing of all the modules started to be performed.

Finally, the canals and the overlaps of fabric against the arches were finished and the polycarbonate sheets were placed (fig. 12).

Fig. 12. Right wing bleachers and roof view.

Fig. 13. Stadium roof at night.

2. GROUP OF TEXTILE UMBRELLAS COVERS FOR THE *SABANA GRANDE* BOULEVARD. CARACAS, CAPITAL DISTRICT. VENEZUELA.

2.1. The umbrella.

The comprehensive Project for the Rehabilitation of the *Sabana Grande* Boulevard contemplated the incorporation of new elements for protection against rain, sun, and wind. The area designated for planting new vegetation was compromised by the *Metro de Caracas* subway tunnel, throughout the entire boulevard. Therefore, it was necessary to seek alternatives.

An “Umbrella”-type structure was chosen. This way, and through the interaction of several of them, grouped in different heights, the natural movement of the trees could be mimicked. On the other hand, the translucent membranes filter the sunlight, allowing the projection of a shadow similar to that of treetops.

The set of covers is formed by six inverted Umbrellas, which cover an approximate surface of about 510 sqm (fig. 14). They have an individual surface of 85 sqm per cover. The base geometry stems from an octagonal plan, confined in a 10 m diameter circumference (fig. 15). As for its height, there are three 9 m tall umbrellas and another group of three which are 8 m tall.

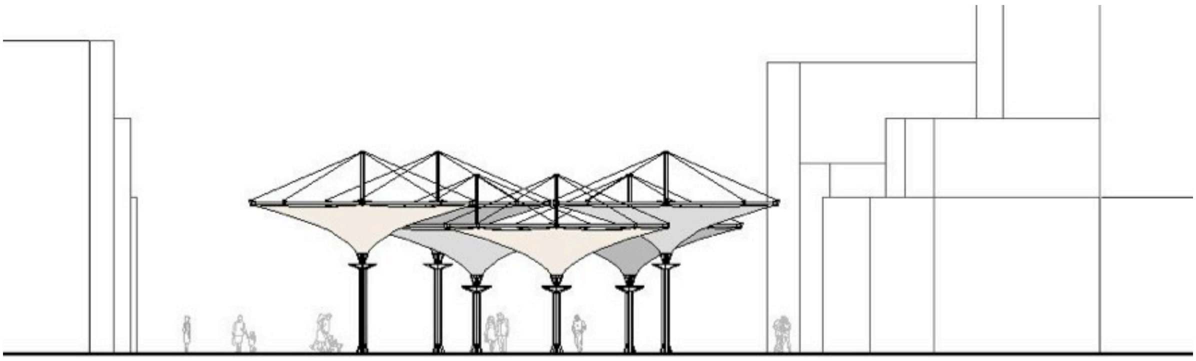
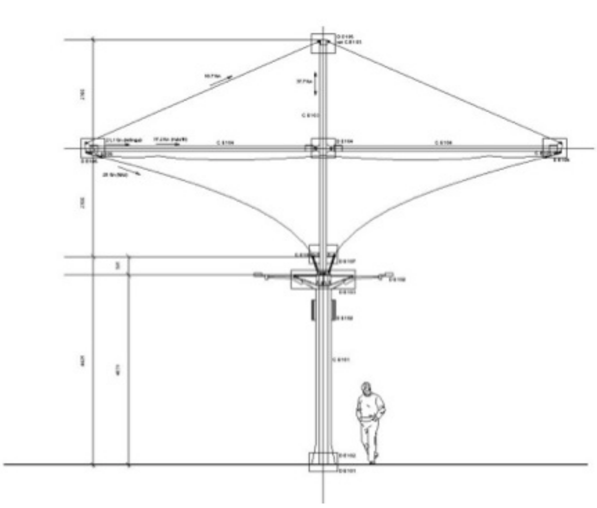


Fig. 14. Boulevard cross section.

The support structure for the membrane is made up of a central mast, divided in two segments. The lower part—where the height difference is located—is reinforced with a group of four flat bars that run along the Ø 194 mm tube, finishing off in the collecting dish, near the connection bridle of the upper part. The upper part (Ø 140 mm tube) is where the textile membrane module is developed, shaped as a cone through its connection to the group of eight Ø 4” and 5m long horizontal struts, suspended radially through steel cables. The lower end of the cone of the membrane finishes off in a stainless steel ring, which permits the definite tensing of the surface, when it is anchored to the bottom end of this section of the mast. The decision to divide the mast in two sections, besides being due to practical reasons regarding manufacture, transport, and manipulation, is the result of the study of the procedure for the on-site assembly, as we will see later.



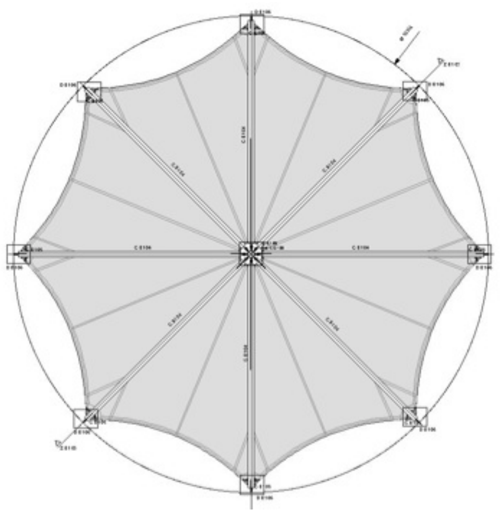
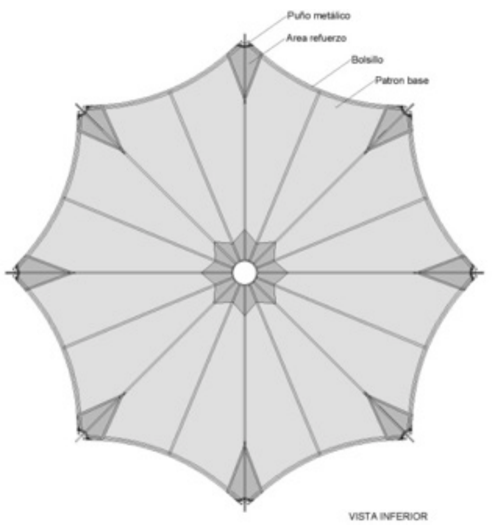


Fig. 15 and 16. The umbrella, section and top view.

The inverted cone, performs like a huge funnel that when it rains, directs the water to a collecting dish located in the bottom segment of the mast. This system allows for the canalization of rain water, through the inside of the masts, to directly enters the boulevard's draining system. The electrical and sound fittings also go inside the pillars for their distribution to the equipment located in the middle of the structure.

2.2. Patterning

The general geometry defines a surface with polar and specular symmetry, which is why it is possible to achieve in the design of a single pattern repeated 16 times (8 of these cuts are mirror cuts) to conform one cover module.



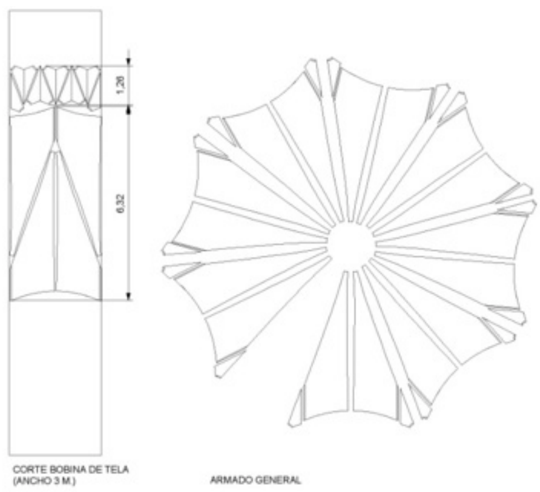


Fig. 17 and 18. Patterns.

In designing the pattern, both the manner to achieve the cut with the least possible waste, as well as the image that can be formed when assembling the cover, are taken into account.

When observing membrane surfaces that are translucent against the light, zones that have a double membrane—overlaps, joints, pockets, reinforcements—appear darker, thus, special attention was paid for this effect to serve the geometry in the cone (fig. 17 and 18).

Before manufacturing the membranes, a physical scale model was built to verify the patterning. The making of the 6 covers took place in a series and included the placement of steel cables and corner plates in the workshop before sending them to the assembly site.

Big Cover—type II—translucent membrane by NAIZIL was the material chosen to make the covers because, aside from fulfilling the necessary structural and resistance requirements, it has the Rotofluo W treatment, which provides it with a lifespan expectation of more than 25 years.

2.3. Assembly

Fig. 19. Assembly and structure erection process.

The umbrella's assembly strategy (fig. 19) was conceived so that upper module of the mast was assembled together with the membrane, temporarily supported on the ground level of the boulevard. So, the pretensed module is raised with the help of a crane and placed over the lower section of the mast that was previously placed in its terminal.

We then proceeded to build the first umbrella. On one side of the corresponding mast, the support tripod was set up for the upper part of the mast, allowing enough space for the maneuver. The steel cable and arms are connected to the upper part of the mast, which lies on the ground. All connections are made using bolts and screws.

Fig. 20 and 21. Assembly and structure erection.

The set is hooked at its upper end by the crane; it is raised and placed in its position, using an assembly tripod for temporary support. The horizontal struts open, taking the package that has the membrane closer to the mast. It is lifted once again, allowing the movement of the membrane from one side to the other. The aim is for the opening of the membrane where the ring is to allow the pillar to pass. The upper part of the mast is lowered to the support of the tripod and the membrane is deployed. The tips of the octagon of the membrane (corner plates) are connected to the heads of the struts.

The ends of the steel cables, which hang from the upper part of the column, are connected with lever chain pullers to the heads of the struts. Slowly, these two elements are brought together, which causes the strut to rise, when it pivots in the node where it meets the mast. A scaffold tower and an additional lever chain puller aids movement, a strut at a time and connects the steel cable to the strut through shackles. The steel cable already has the size defined by the project and has been prepared in the workshop. The membrane is tensed through the central ring, and using four lever chain pullers it is taken to its position. Four chains connect the ring to the mast and the lever chain pullers are taken off.

The crane lifts the pretensed module and takes the upper part of the mast to its place (fig. 20 and 21). There is a telescopic-type connection between the lower and upper part, which is fit using a bolted bridle. The electrical and sound fittings run inside the pillar. Therefore, special attention is paid when making this connection.

In the six umbrellas, the strategy for the assembly was similar, but, due to the experience gained in the assembly of the first ones, times improved. This procedure prevented the need for working at heights, which would have further complicated the assembly and probably would have compromised the deadline.

Fig. 22. Umbrellas at the boulevard.

2.4. Lighting and sound

White, direct light was chosen since it is the most adequate for the presentation of everyday cultural, commercial, and traffic activities. This lighting will be carried out with 7W LED luminaires, which will be installed on a metallic trapezoidal piece, located between the flat bars that form the base of the rain water collecting dish (Fig. 23).

Fig. 23. Direct light luminaries.

To highlight the structures as so to give them an architectural overtone, we chose a system that offers changes in light colors and effects on the surface of the membrane, whereas in the masts, the lighting will be fixed in blue.

Fig. 24 and 25. Umbrellas at night.

To achieve this result, we use 8 LED RGB luminaires, handled by a DMX wireless transitioning controller. These luminaires will be installed on arms specially designed to hold them, which will allow them to be moved closer to the ends of the cover in order to achieve a better coverage (fig. 24 and 25).

To light the masts and the dish we use bidirectional projecting luminaires. Each one has two 3W LED bulbs. Out of these bulbs, 4 will be oriented towards the ground, in order to color the mast, and 4 will be oriented upwards to color the rain water collecting dish.

To this type of monumental lighting we incorporate an integral sound system, which allows the programming of moments of interaction between music and lighting. Two sound tracks were specially produced to alternate between day and night environments in which sounds of nature are conjugated with musical arrangements aimed to help the users of that place relax.